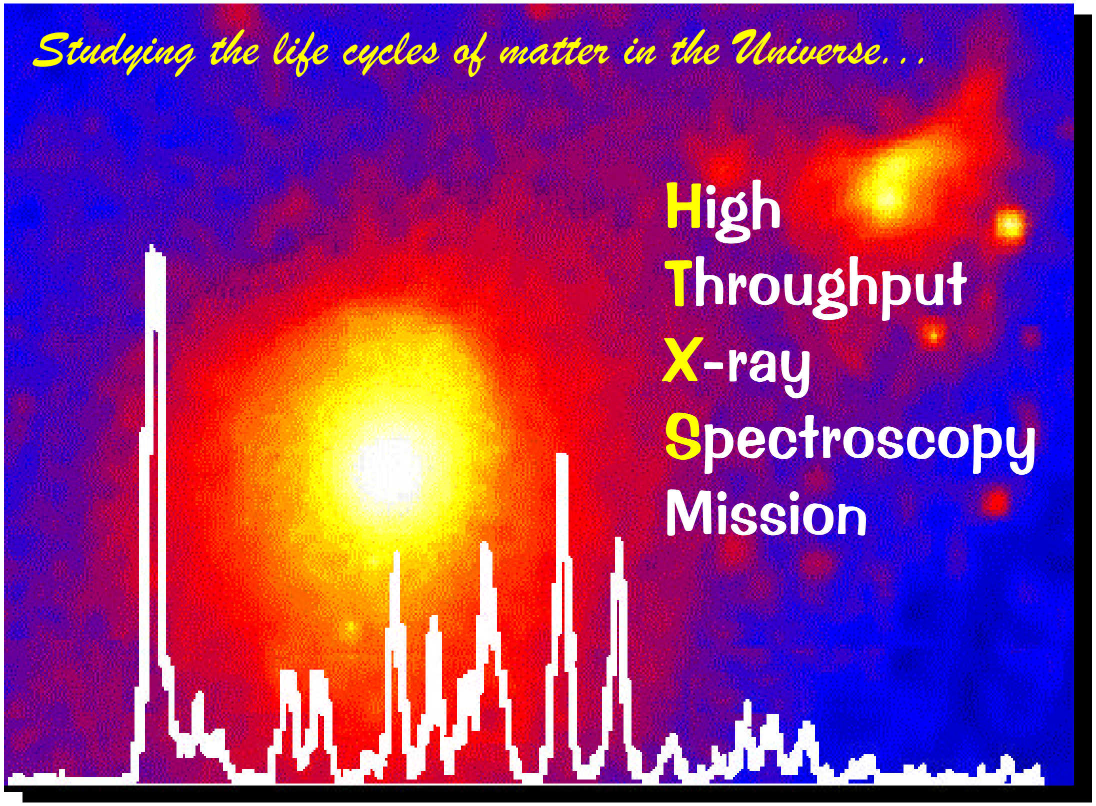
The High Throughput X-ray Spectroscopy (HTXS) Mission

Nicholas White (GSFC) and Harvey Tananbaum (SAO)



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University of Arizona
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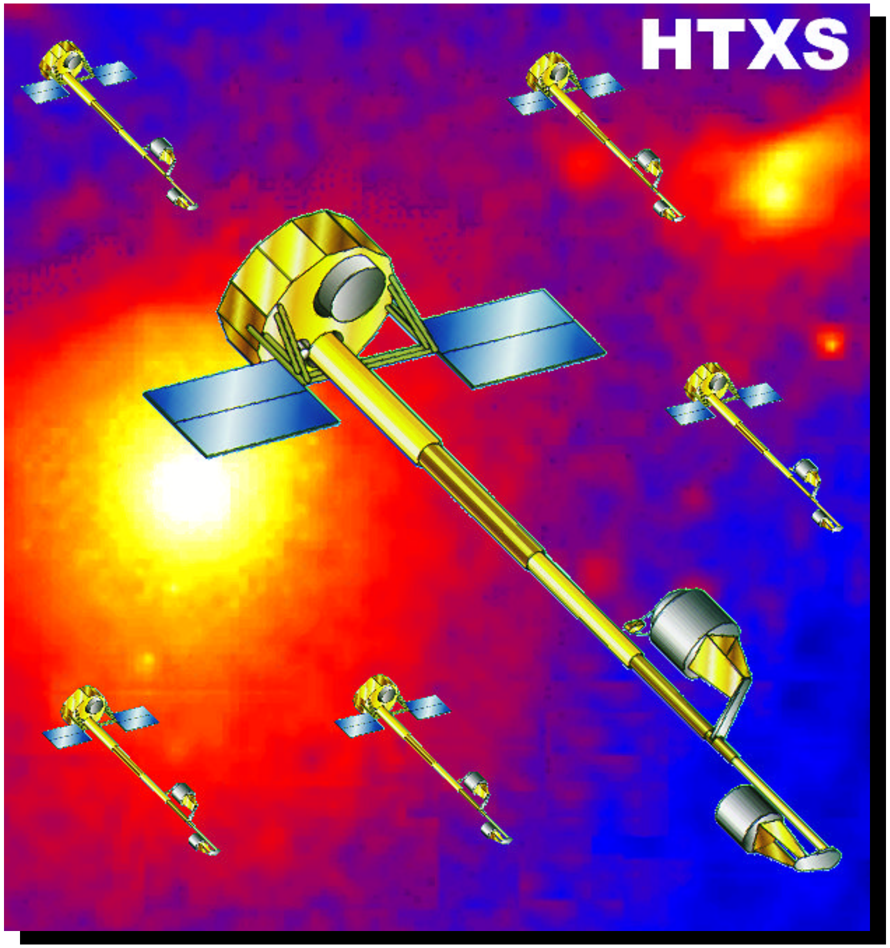
http://htxs.gsfc.nasa.gov

High Throughput X-ray Spectroscopy Mission

Studying the life cycles of matter in the Universe



- Key scientific goals
  - Elemental abundances and enrichment processes throughout the Universe
  - Parameters of supermassive black holes
  - Plasma diagnostics from stars to clusters
- Mission parameters
  - Effective area: 15,000 cm^2 at 1 keV
    150 times AXAF for high resolution spectroscopy
  - Spectral resolving power: 3,000 at 6.4 keV
    5 times Astro-E calorimeter
  - Band pass: 0.25 to 40 keV
    100 times increased sensitivity at 40 keV

HTXS Mission History

HTXS is the merging of two peer-reviewed mission concepts selected by NASA in March 1995 for possible flight during the next decade:

- ***The Next Generation X-ray Observatory*** -
  PI: Nicholas E. White (NASA/GSFC)
- ***Large Area X-ray Spectroscopy Mission -***
  PI: Harvey D. Tananbaum (SAO)

Also now includes elements of a third accepted mission concept proposal,
Hard X-ray Telescope - PI: Paul Gorenstein

Capabilities endorsed as the priority next generation X-ray facility at Leicester NGXO Workshop attended by representatives from 25 Institutions from ten different countries

Addresses several primary and secondary science priorities of the TGSAA report including

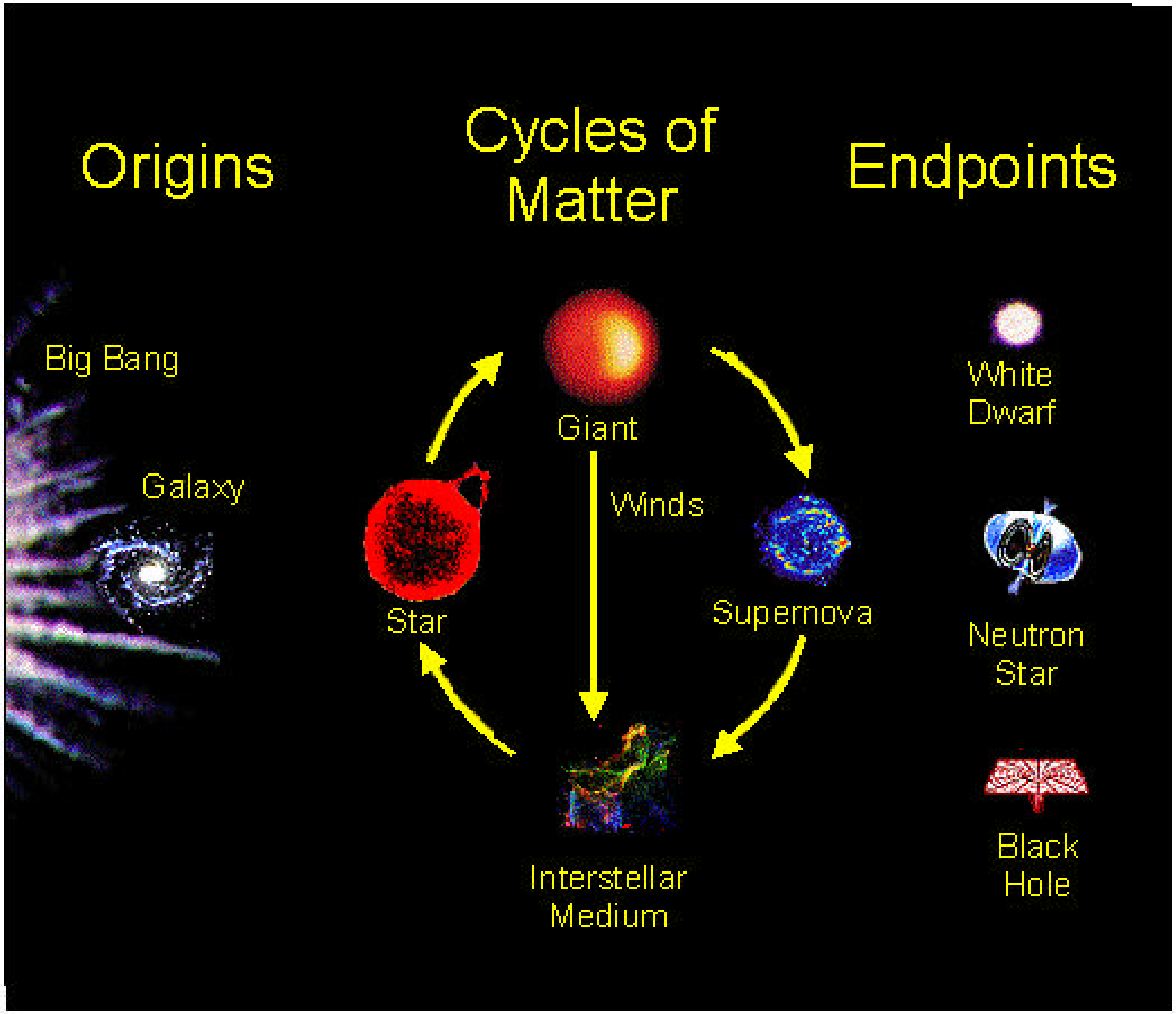
- Measurement of the properties of black holes of all sizes
- Study of the origin and evolution of the elements

Selected in May 1997 as a new mission to be proposed for a FY2004 new start at the Space Science Enterprise Planning *Breckenridge* Workshop

Studying the Life Cycles of Matter with the HTXS Mission

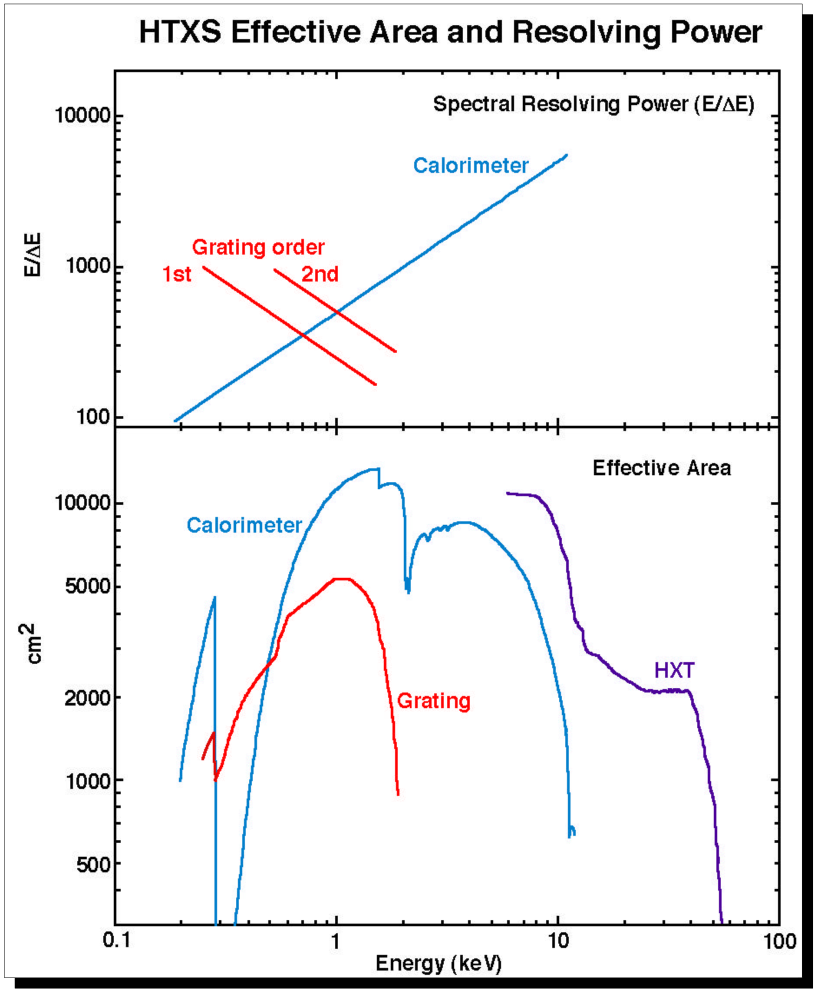
Obtain high quality X-ray spectra for all classes of X-ray sources over a wide range of luminosity and distance to determine:

- the abundance of elements with atomic number between Carbon and Zinc (Z=6 to 30) using line to continuum ratios
- the ionization state, temperature, and density of the emission region using plasma diagnostics
- the underlying continuum process with a broad bandpass
- dynamics from line shifts and line broadening



HTXS Science Payload

Two coaligned telescope systems cover the 0.25-40 keV band.



A spectroscopy X-ray telescope (SXT) from 0.25 to 10.0 keV

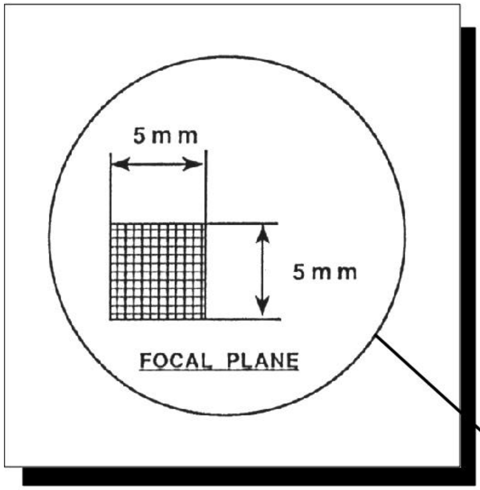
- an array of microcalorimeters with 2 eV resolution.
- a reflection grating/CCD to maintain resolution > 300 below 1 keV

A hard X-ray telescope (HXT) for 10 to 40 keV

- grazing incidence optics
- an energy resolution ~1 keV, sufficient to measure the continuum

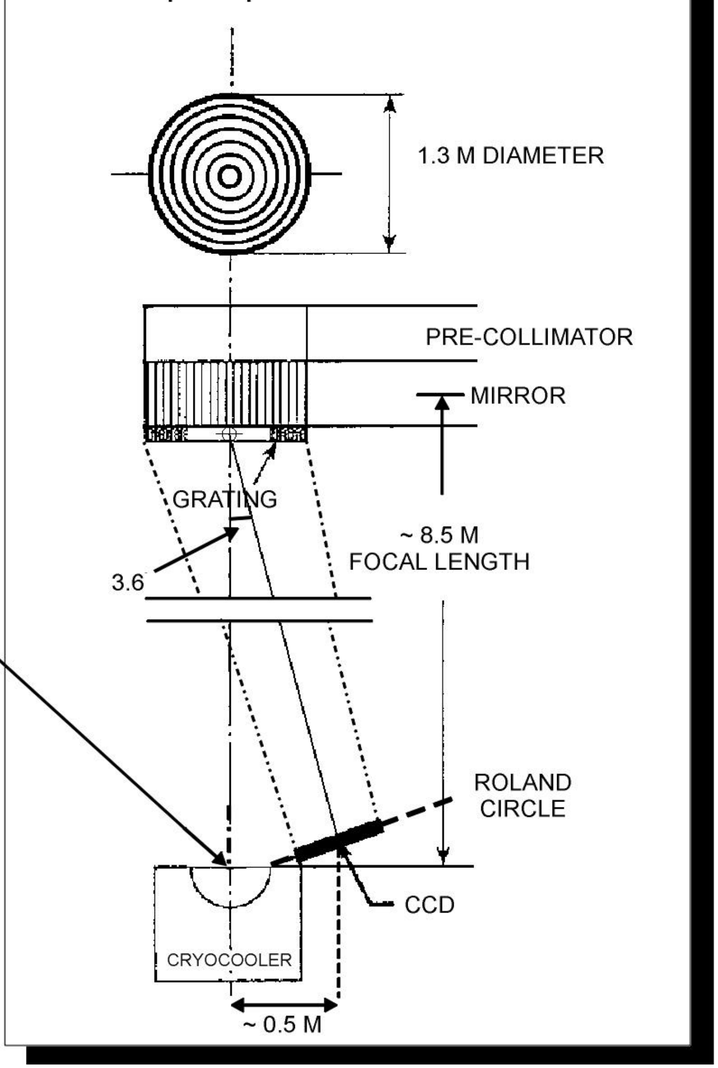
HTXS Instrumentation

Calorimeter Array



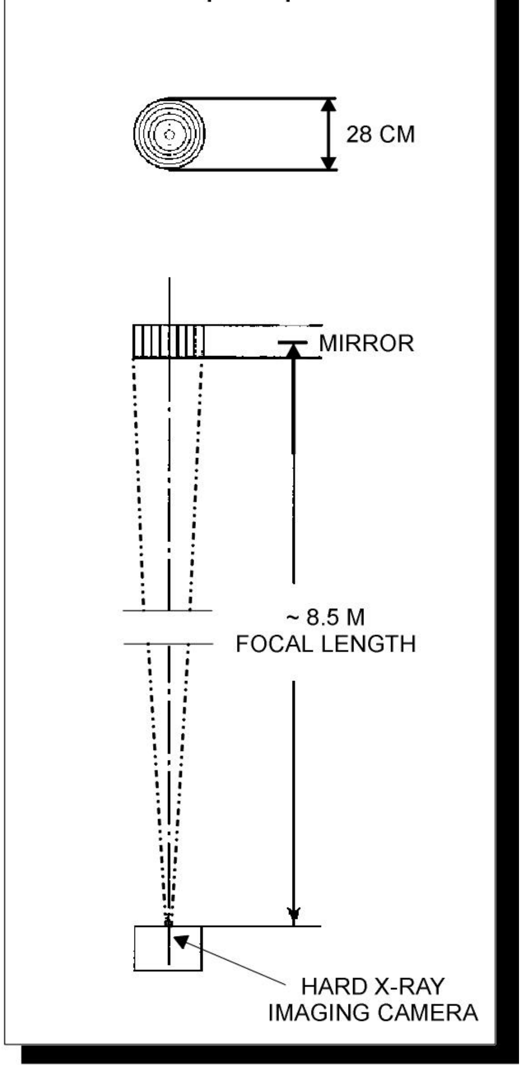
Spectroscopy X-ray Telescope

One unit per spacecraft

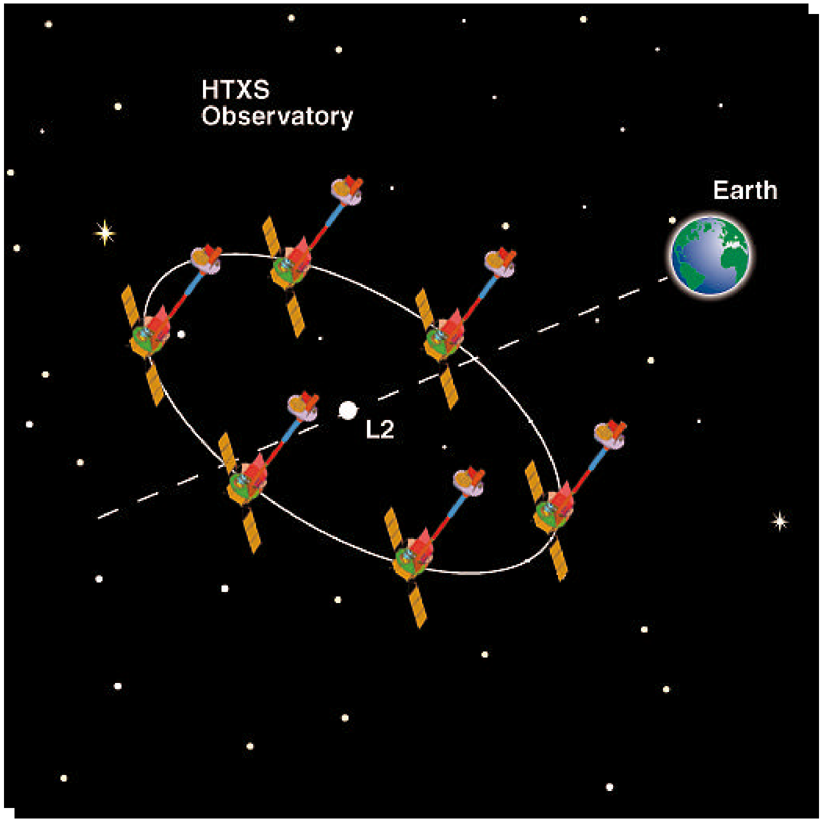


Hard X-ray Telescope

Three units per spacecraft



A Multi-Satellite Approach to Large Collecting Area



To achieve 15,000 cm^2 effective area on a single satellite requires a Titan-class launch.

An alternative low-risk approach to achieve large X-ray collecting area is to utilize six identical low-cost Delta-class satellites.

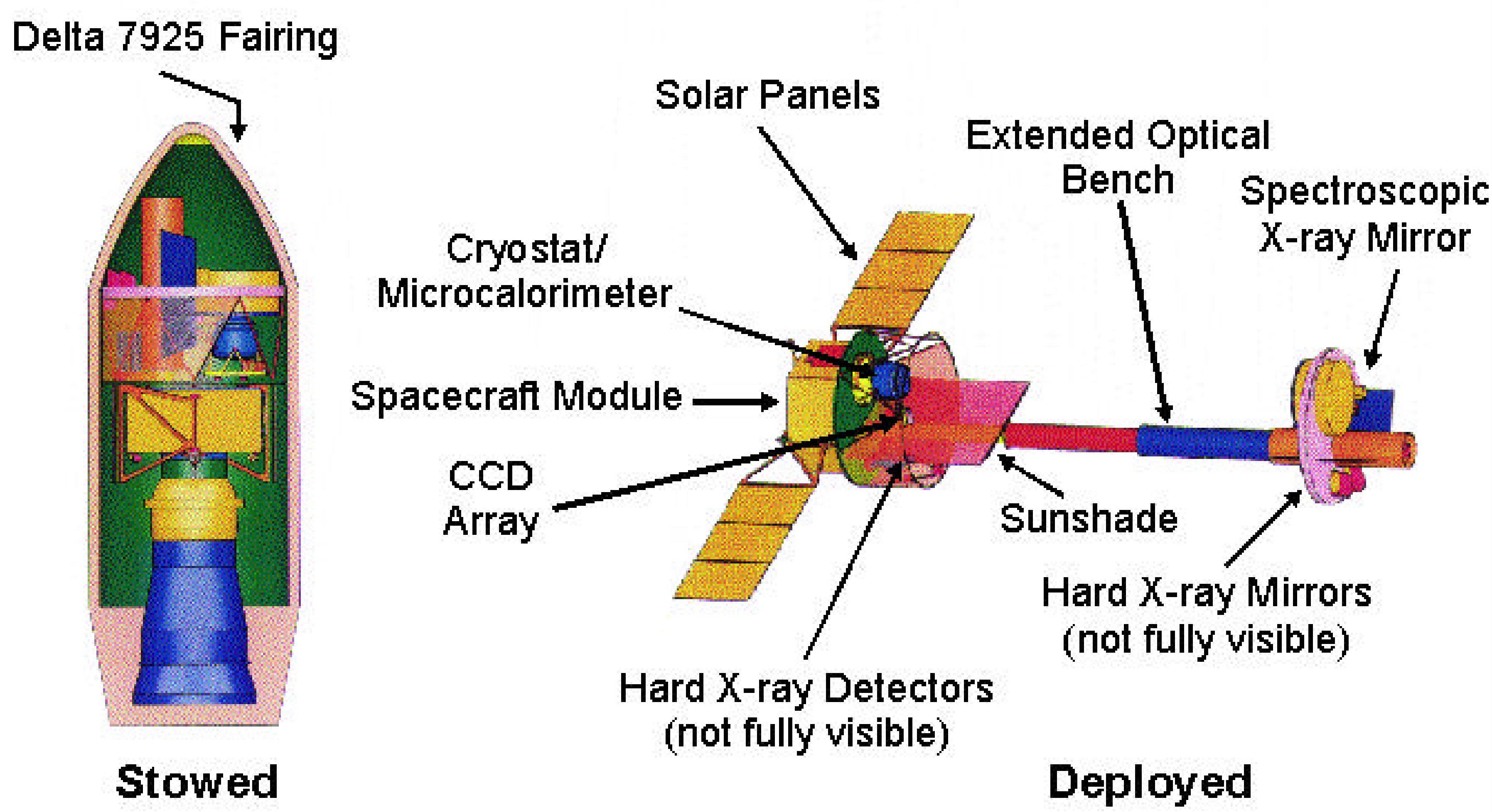
Launch intervals of three months.

Facilitate simultaneous viewing and high efficiency by using libration point orbit.

The telescopes require a focal length of 8.5 m and use an extendible optical bench to allow a Delta-class launch.

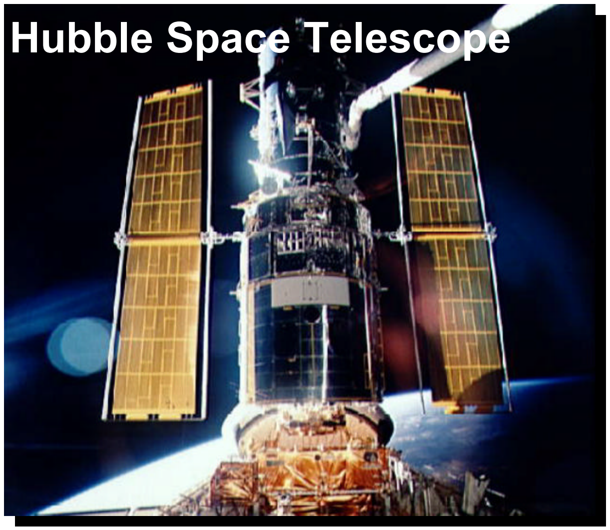
Each spacecraft design lifetime is three years, with consumables targeted for a five-year mission.

HTXS Reference Design

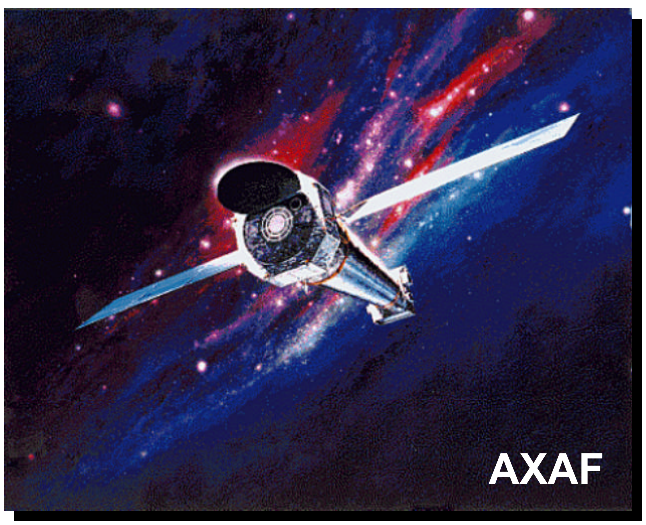


Trade-offs: Angular Resolution vs Area

Imaging

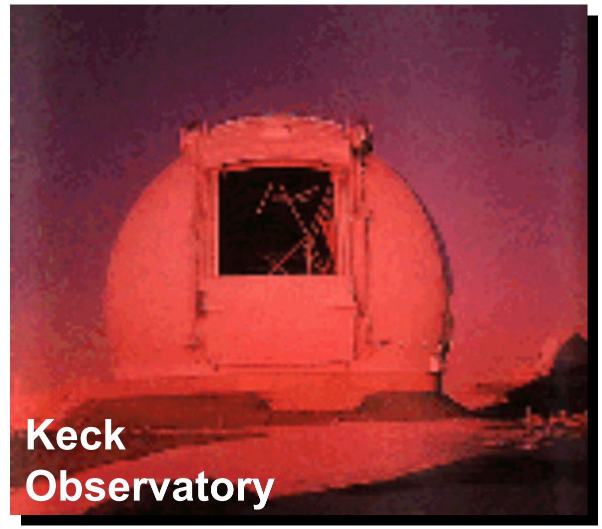


0.1 arc sec
40,000 cm^2

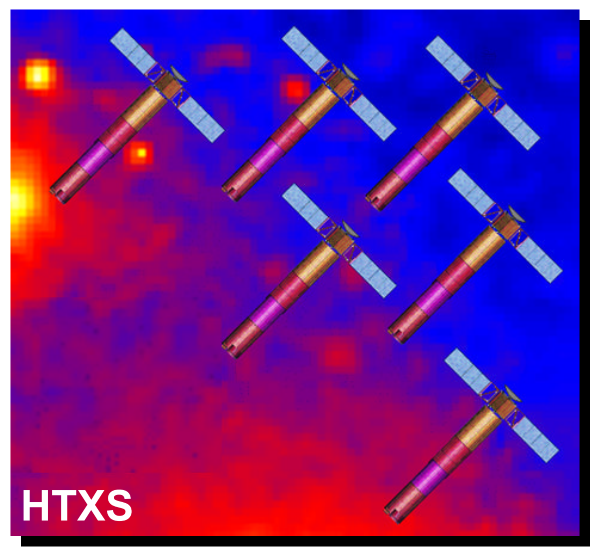


0.6 arc sec
1,000 cm^2
(100 cm^2)

Spectroscopy



1 arc sec
780,000 cm^2

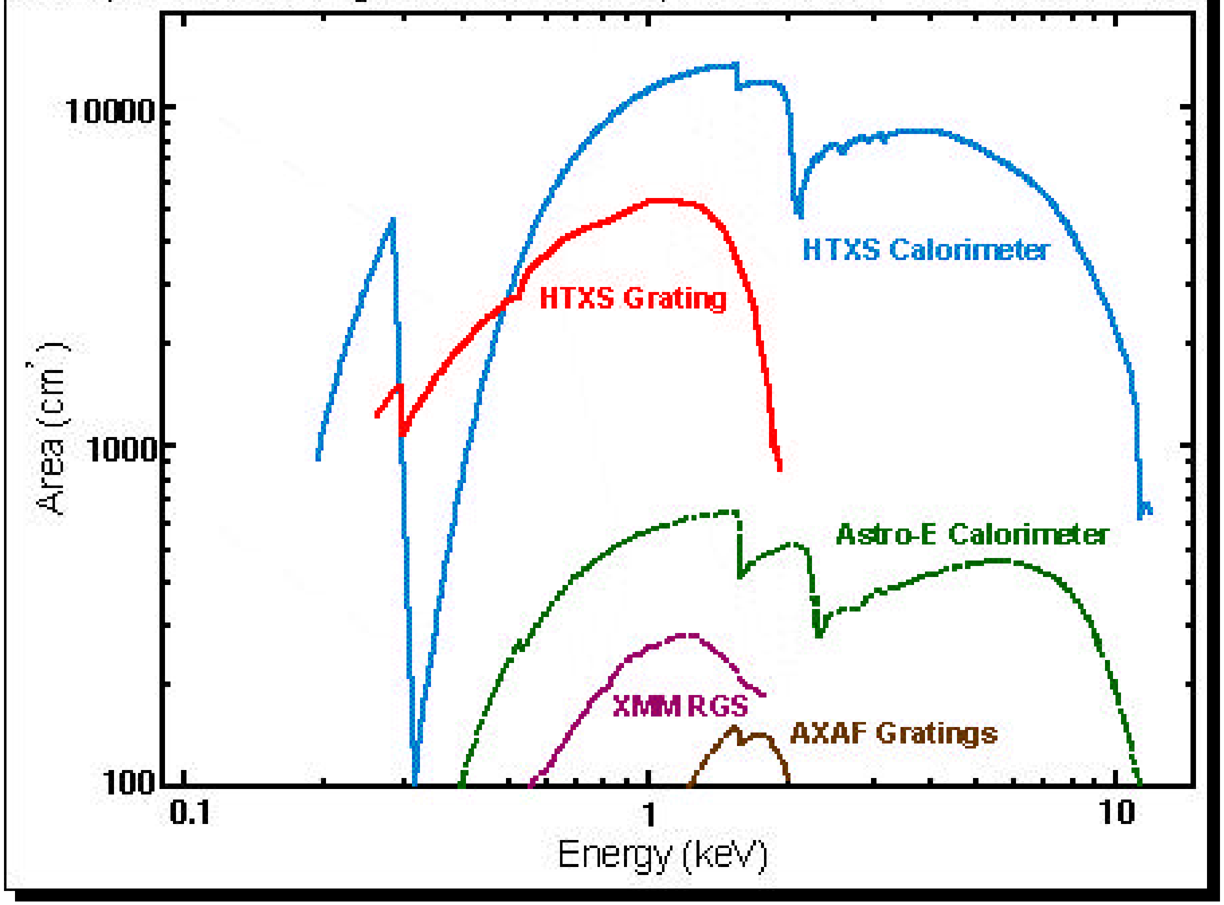


15 arc sec
30,000 cm^2
(15,000 cm^2)

* effective area at the spectrometer

HTXS Advanced Capabilities
I. High Throughput

Comparison of High Resolution Spectrometer Effective Areas

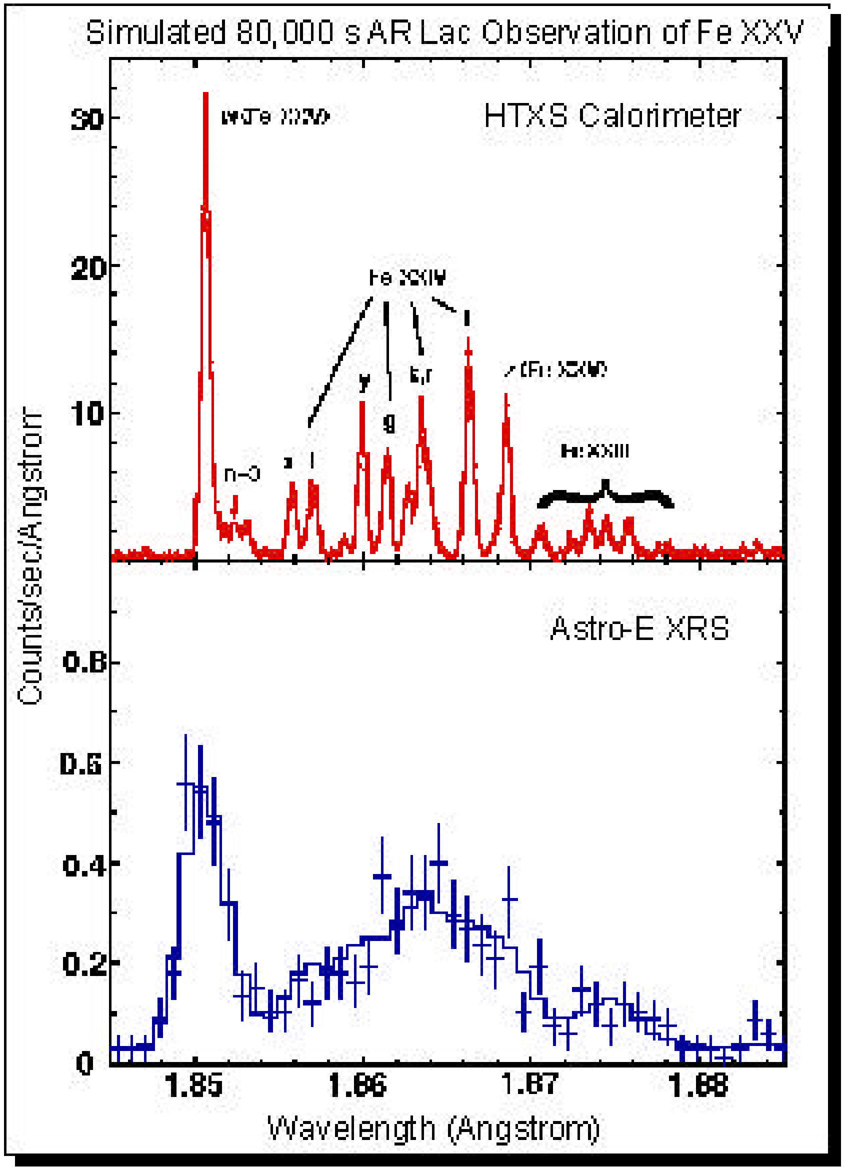


A 20-100 fold gain in effective area for high resolution X-ray spectroscopy

High throughput optics plus high quantum efficiency calorimeters

Lightweight reflection gratings maintain resolution and coverage at low energies (< 1 keV)

HTXS Advanced Capabilities
II. High Spectral Resolution



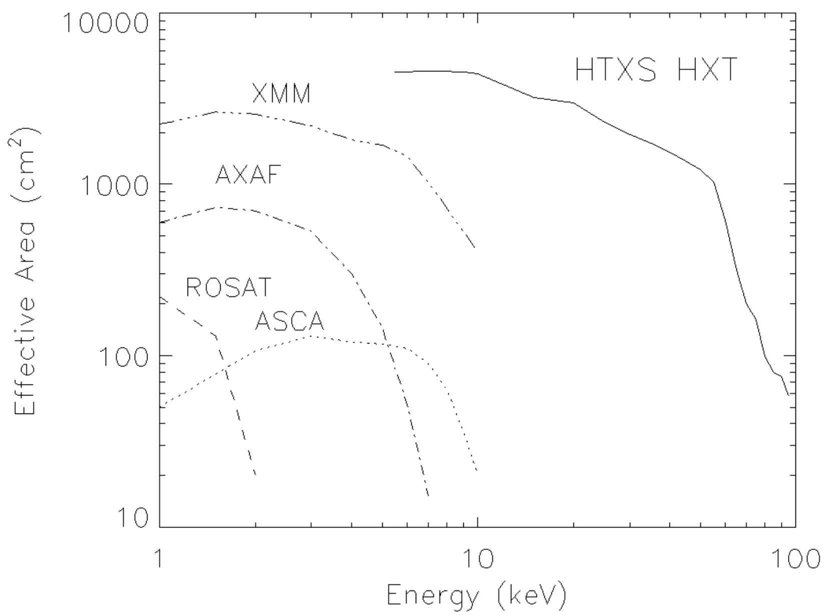
The Next Generation Microcalorimeter Array

High quantum efficiency with the capability to map extended sources

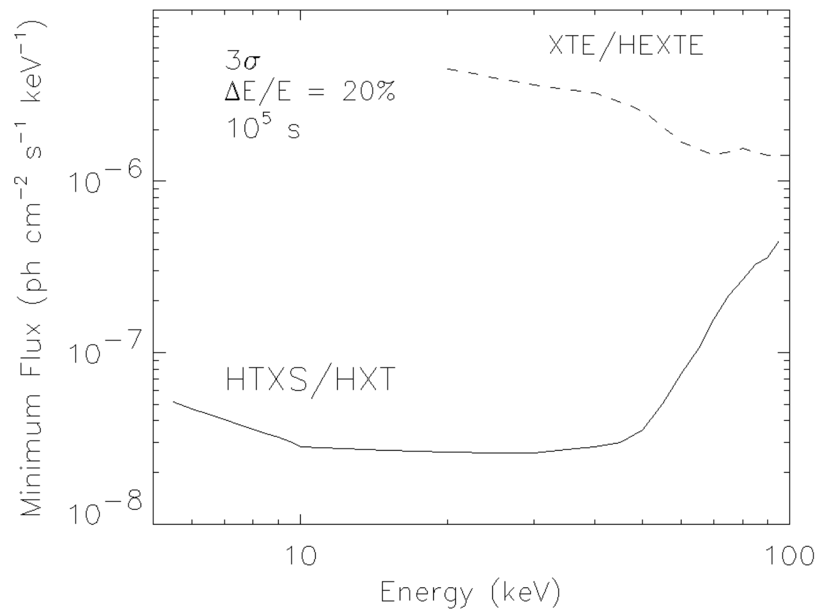
- A factor of 5 improvement (to 2 eV) in spectral resolution
- Successor to the calorimeter to be flown on Astro-E (2000-2002)
- At Iron K, 2 eV resolution gives a velocity diagnostic of 10 km/s

HTXS Advanced Capabilities
III. Broad Bandpass

Multilayer coatings to enhance high energy response



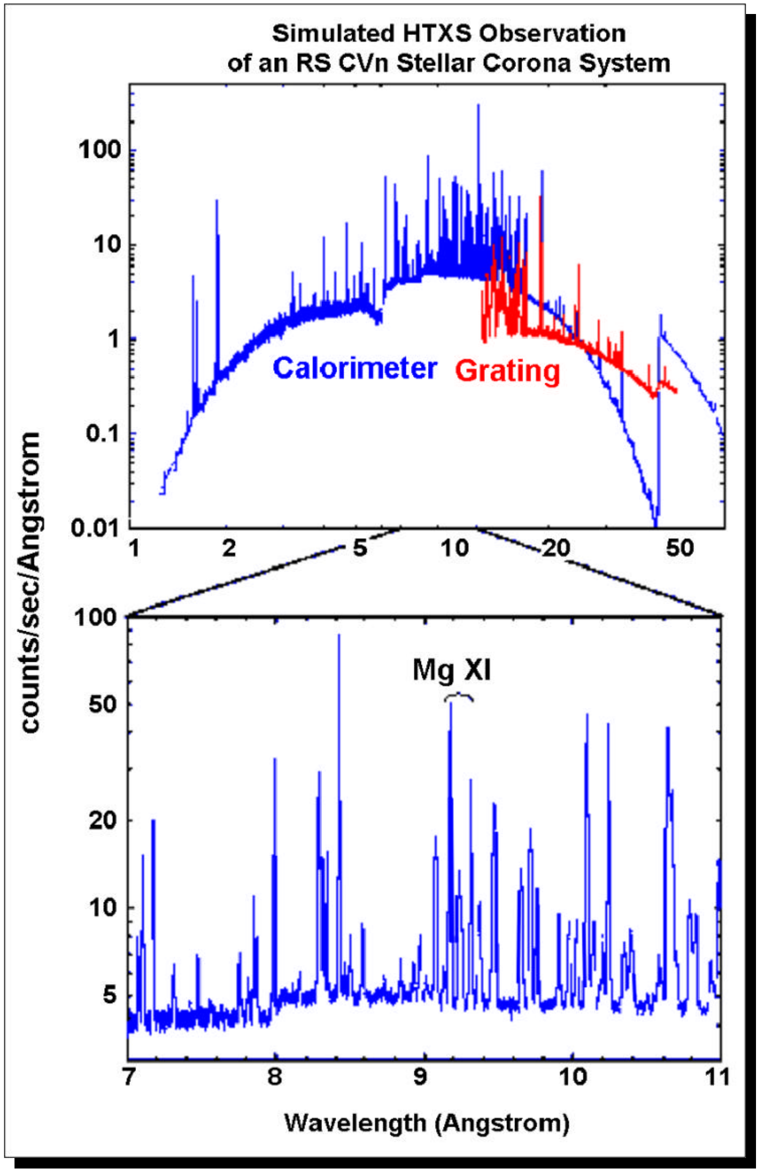
Effective area as a function of energy
for baseline HXT design.



Continuum sensitivity as a function
of energy for baseline HXT design

- No previous instrument has employed focusing in the Hard X-ray band
- Dramatic sensitivity improvements will be achieved

Abundance Determinations using HTXS



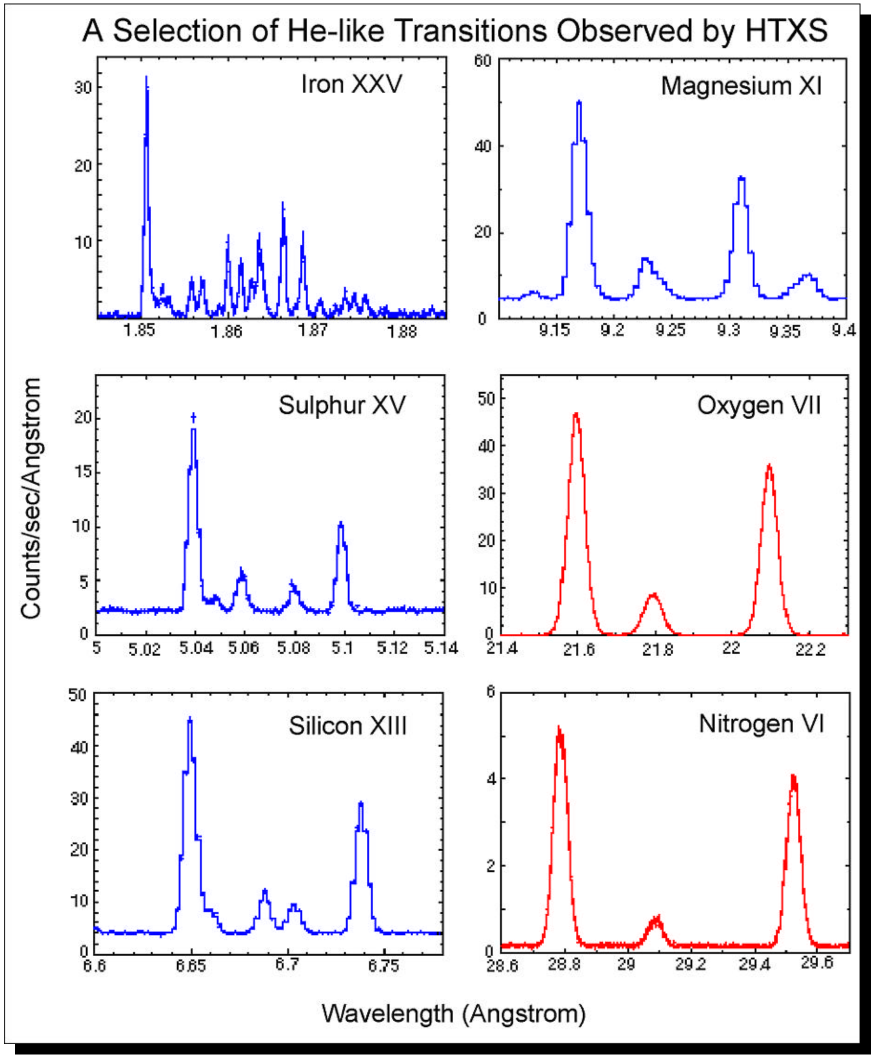
The HTXS energy band contains the K-line transitions of 25 elements allowing simultaneous direct abundance determinations using line-to-continuum ratios

The sensitivity of HTXS will allow abundance measurements in:

- the intracluster medium in distant clusters,
- the halos of elliptical galaxies,
- starburst galaxies,
- stellar coronae,
- young and pre-main sequence stars,
- X-ray irradiated accretion flows, and
- supernova remnants and the interstellar medium.

Temperature, Density, and Velocity Diagnostics

The spectral resolution of HTXS is tuned to study the He-like density sensitive transitions of Carbon through Zinc



Direct determination of

- densities from 10^8 to 10^{14} cm^{-3}
- temperature from 1-100 million degrees.

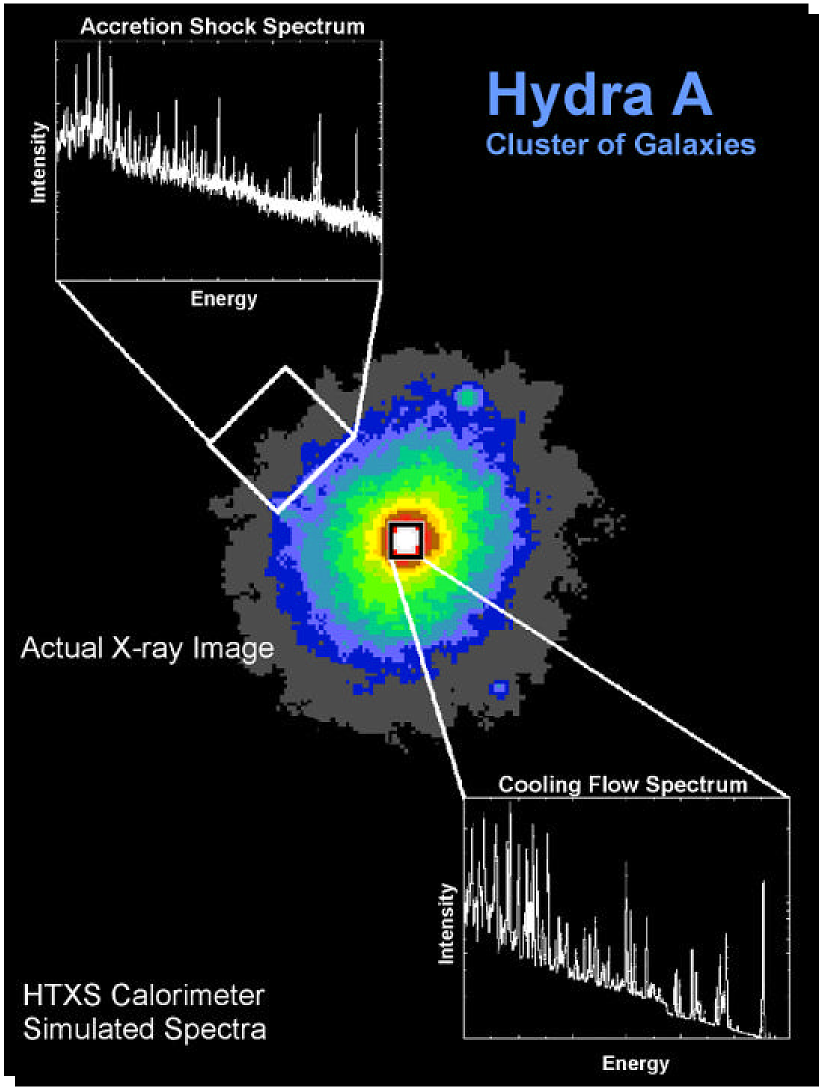
Velocity diagnostics at Fe K line:

- line width gives a bulk velocity of 100 km/s
- line energy gives an absolute velocity determination to 10 km/s

Simultaneous determination of the continuum parameters

HTXS Observations of Clusters of Galaxies

Baryon content of Universe is dominated by hot X-ray emitting plasma

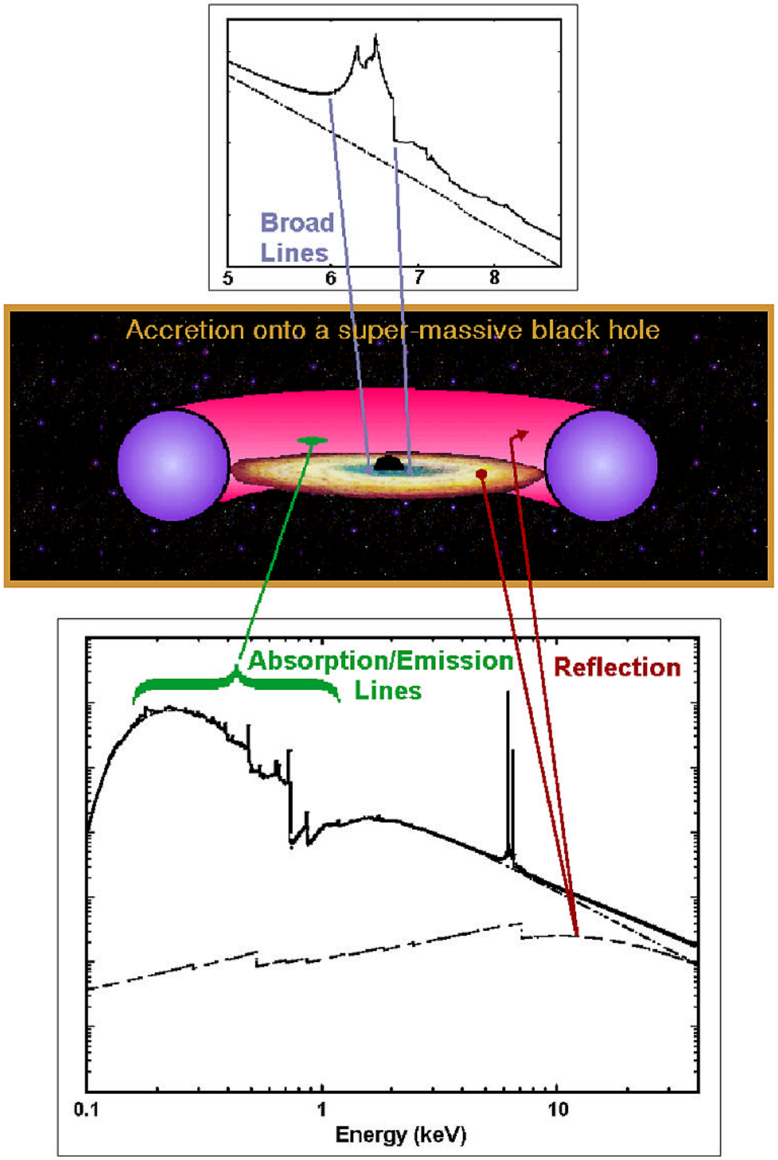


Clusters of galaxies are the largest and most massive objects known

HTXS cluster observations essential for understanding structure, evolution, and mass content of the Universe

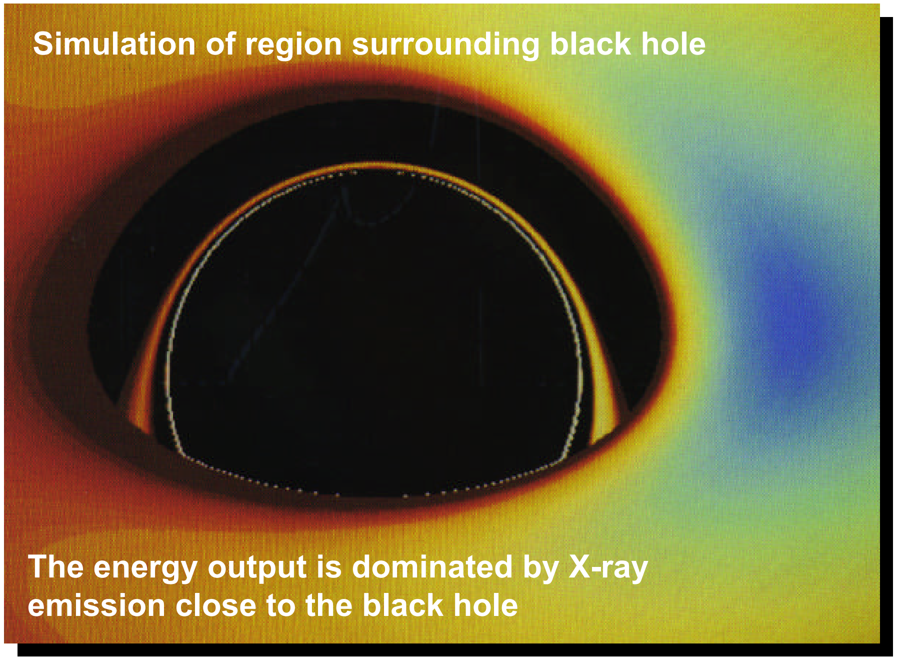
- Observe epoch of cluster formation and determine changes in luminosity, shape, and size vs redshift
- Measure abundances of elements from carbon to zinc, globally mapping generation and dissemination of seeds for earth-like planets and life itself
- Map velocity profiles, probing dynamics and measuring distributions of luminous and dark matter

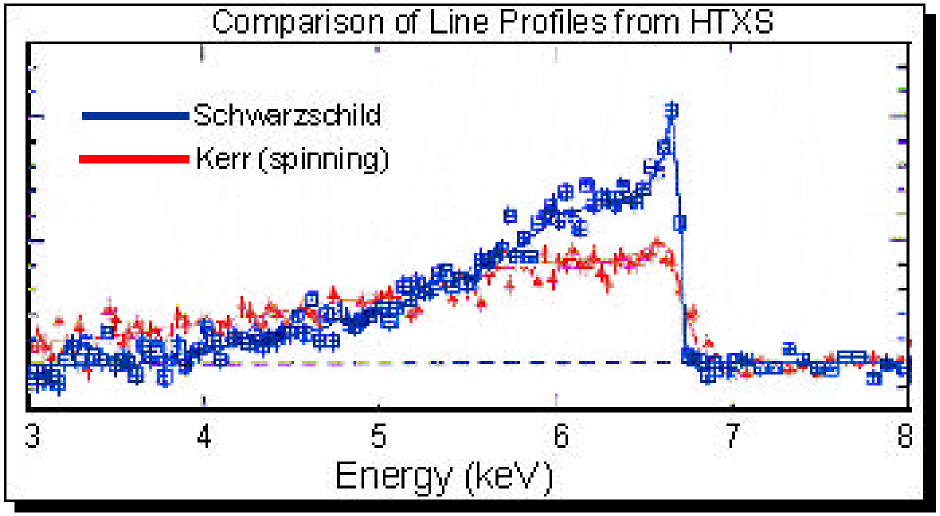
HTXS Observations of Supermassive Black Holes



- Obtain the first detailed X-ray spectra of AGN out to redshift 5
- Study the faint AGN populations
- Resolve narrow X-ray emission line components in the spectra of AGN
- Test general relativity in the strong gravity limit.
- Determine the rotation rate and mass of black holes
- Determine the geometry of the accretion flow

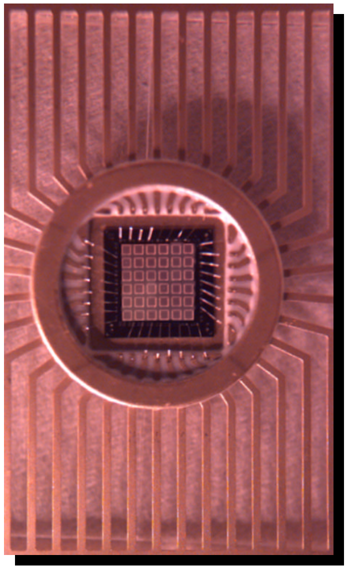
HTXS Will Determine the Nature of Super-Massive Black Holes



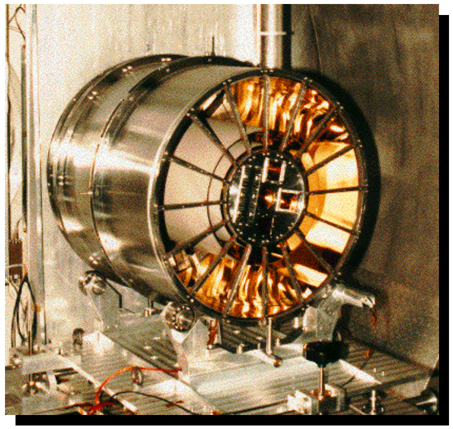


- Active galactic nuclei and quasars powered by accretion of matter onto supermassive black holes
- X-rays produced near event horizon and probe 100,000 times closer to black hole than HST
- Relativistically broadened iron lines probe inner sanctum near black holes, testing GR in strong gravity limit
- HTXS will determine black hole mass and spin using iron K line
  - Spin from line profiles
  - Mass from time-linked intensity changes for line and continuum

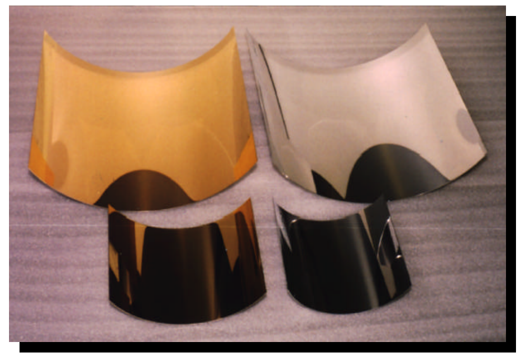
HTXS Technology Requirements



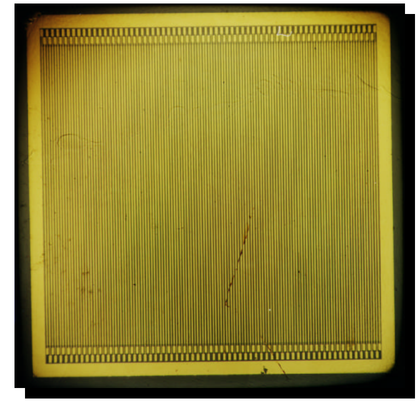
Microcalorimeters



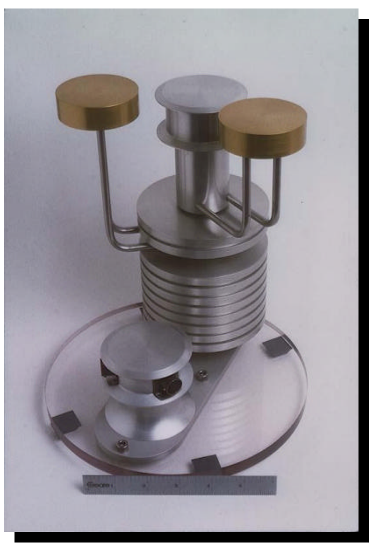
Lightweight
X-ray Optics



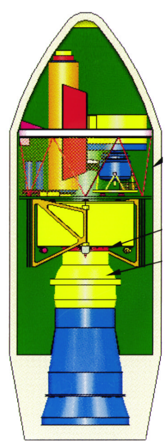
Multilayer Coatings

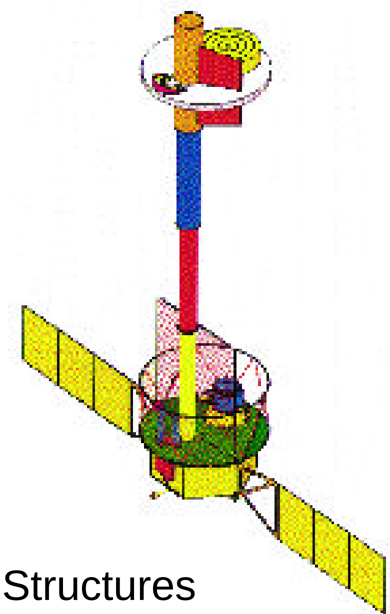


CdZnTe Arrays



Coolers

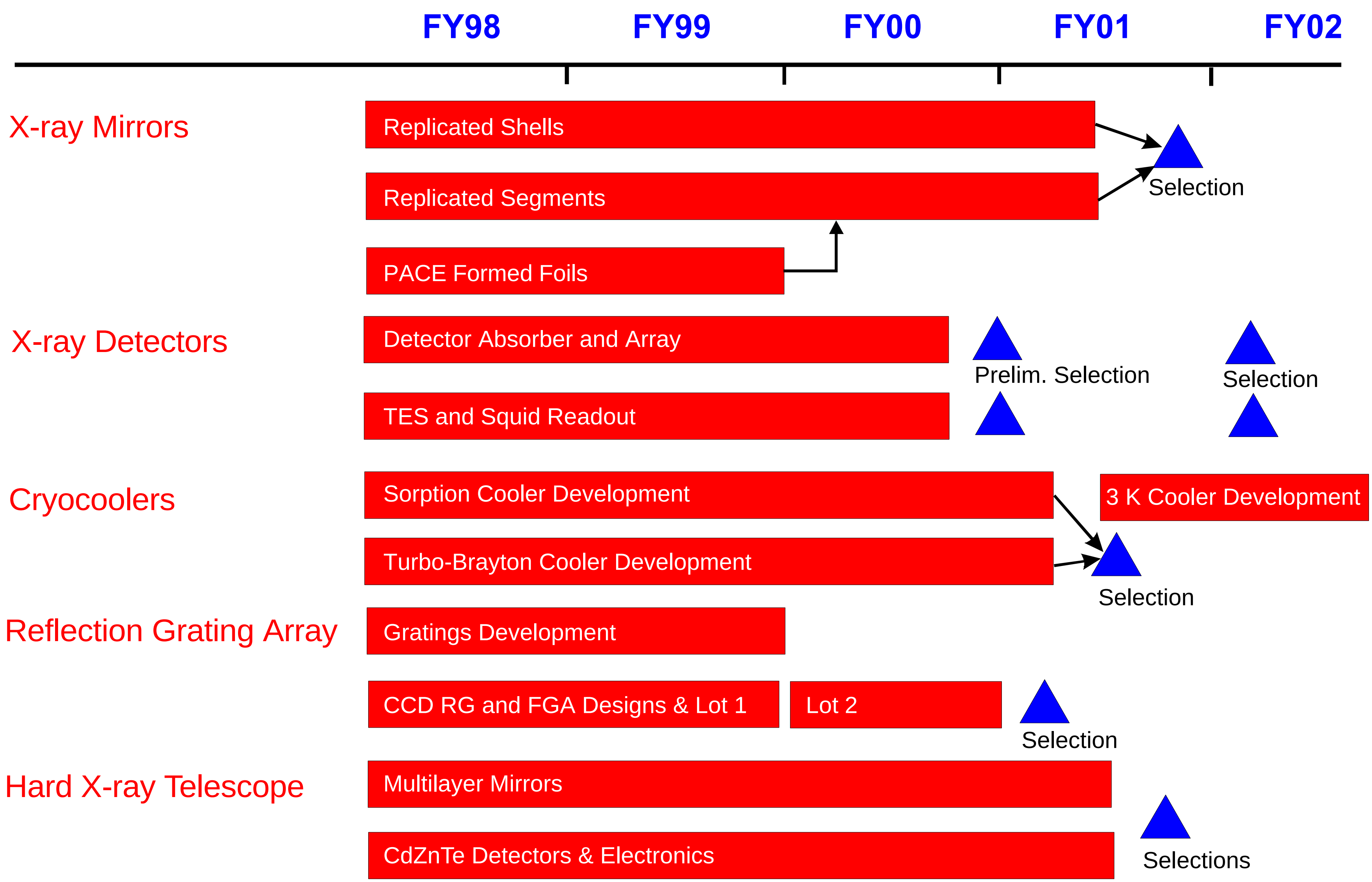




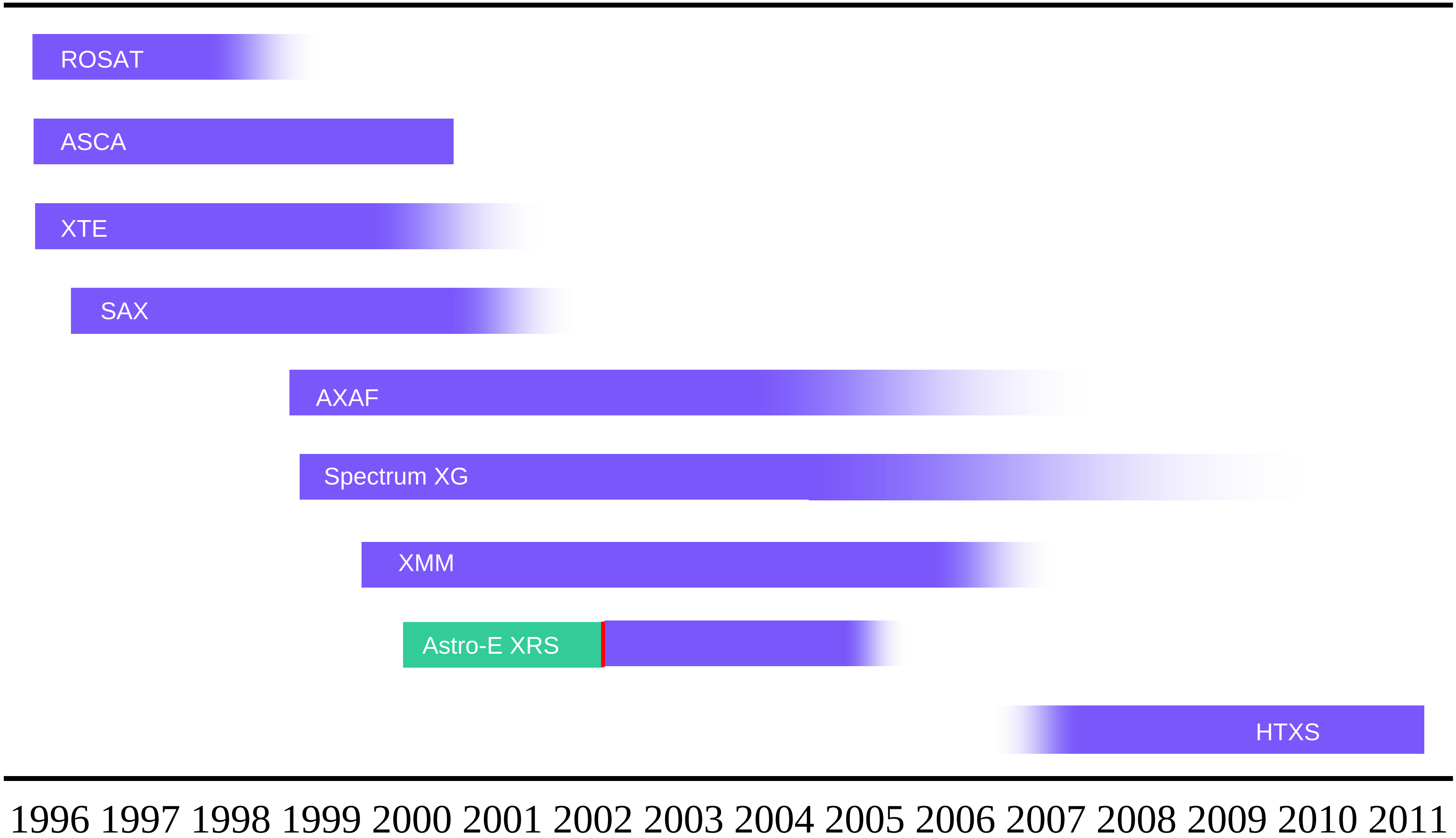
Deployable Structures

Autonomous
Operations

HTXS Technology Roadmap



X-ray Observatories Timeline



The Outlook for HTXS

Summer of 1998...

- Technology development efforts have begun in earnest
- Mission concept study has demonstrated mission feasibility to next level of detail
- Cost estimates and Phase B/C/D schedule have been refined
- Acquisition strategy has been developed
- Outreach program underway

Summer of 2002...

- Phase B is halfway complete
  - Mission contractor has been selected
  - Systems Requirements Review has just taken place

- Technology developments required for HTXS are complete
  - Selections made between competing technologies

HTXS International Collaboration

International participation in HTXS is encouraged

- Too soon to make specific agreements on contributions until the technology is selected
- Current emphasis on contributing to the technology development program

Current arrangements and teaming:

- Osservatorio Astronomico di Brera (Italy)/SAO/MSFC developing lightweight replicated shell optics
- Nagoya University (Japan)/GSFC: Multilayers for HXT
- Danish Space Research Institute/CalTech: Multilayers for HXT
- MSSL (UK)/GSFC: Two-stage ADR
- Leicester University (UK)/GSFC: Microchannel plates for HXT

Summary

HTXS traces the evolution of the Universe from origins to endpoints

- the production and recycling of elements
- the origin and evolution of black holes

Investment now beginning to develop advanced technology to enable the mission

- assembly line production of lightweight, high performance optics, detectors, coolers, and spacecraft
- Multi-satellite concept is low-risk

Facilitates ongoing science-driven, technology-enabled extensions*:*

- spatial resolution,
- collecting area,
- energy bandwidth, and
- spectral resolution

http://htxs.gsfc.nasa.gov